Chapter 2
Description and Application

2-1. General

Vertical lift gates are used for navigation lock chamber gates, emergency closure gates for powerhouse intakes and outlet works, and spillway crest gates. Each type of gate used has its advantages and disadvantages and is designed to accommodate special requirements for closure and retention of hydraulic head.

2-2. Gate Types and Applications

a. *Navigation locks*. Navigation locks may use overhead or submersible lift gates and are described below. EM's 1110-2-2602, 1110-2-2607, and 1110-2-2703 provide information on other types of gates for navigation locks.

(1) Overhead gates. These types of gates use a tower with overhead cables, sheaves, and bullwheels to support the gate during its operation and counterweights to assist hoisting machinery. The tower height is governed by the lift required to pass barge traffic. These gates can be a plate girder, horizontal tied arch, or horizontal truss, which are discussed in Chapter 3. Examples of a horizontal truss and tied arch are shown in Plates 1-3. These gates are often used as tide or hurricane gates along the seacoast and for inland navigation locks. When they are used as hurricane gates, they are normally raised to permit normal water traffic to pass underneath and lowered to protect harbors from tidal storm surges. This type of gate would be used in the following situations: it is not practical to use submersible gates (as with high-head applications); when sufficient support cannot be provided for transferring thrust from miter gates; the available area to place the gate monolith is limited and will not permit the use of miter gates; or when the gate is used as a hurricane or tide gate and is subject to reverse hydrostatic or hydrodynamic loadings.

(2) Submersible gates. A submersible gate can be used as the upstream gate for a navigation lock, where the submersible leaf rests below the upstream sill. There are two types of submersible gates: single leaf and multiple leaf. The double leaf arrangement is most common. It is composed of a downstream leaf, used for normal lock operation, and an upstream leaf, used infrequently as a movable sill or as an operating leaf in an emergency. This is referred to as the emergency leaf. An example of a downstream leaf is shown in Plates 4 and 5. Both leaves are normally constructed of horizontal girders with an upstream skin plate. The hoist components at either side of the lock are mounted above the high water in a concrete recess with a removable roof section. The powered hoist component is mounted on a structural steel frame anchored to a concrete structure on one side of the lock. The nonpowered component is then mounted on the opposite wall. For the normal open or stored position, the leaves are lowered into the sill. The emergency leaf is used for lock closure in the event of an accident or damage to the gate that would otherwise result in loss of the navigation pool. This type of gate is useful when it is necessary to skim ice and drift from the lock approaches or open the lock gates to pass flood flows.

b. *Spillway crest*. This type of gate is sometimes preferred over tainter gates because the spillway crest requires a shorter length of spillway pier and provides a more economical pier design. These gates are usually raised by using the gantry crane or fixed hoists for each gate located on the spillway deck or operating platform. Dogging devices are sometimes provided to engage projections spaced at intervals on the gate to hold the gate at the proper elevation. In some cases it may be advantageous to mount the dogs in the gate and provide a dogging ladder in the gate slot; however, the other arrangement is preferred. Different types of spillway crest gates are as follows:

(1) Single section. This gate consists of one section that provides a variable discharge between the bottom of the gate and the sill. Single-section gates operate similarly to the multiple-section gates but are dogged off in the service slots.

(2) Multiple section. A multiple-section gate consists of two or more sections in the same slot with variable discharge between the sections or between the bottom section and the sill. Multiple-section gates can be equipped with a latching mechanism to allow use as a single-section gate. As the required discharge increases beyond the capacity of the largest opening between sections, top sections are removed from the service slots and dogged above the pool level in emergency slots. The latching mechanisms should be carefully designed so they do not stick or corrode. This has been a maintenance problem for some projects. The top section of a multiple-section gate is shown in Plate 6.

(3) Double section. This gate consists of two sections in adjacent slots with variable discharge over the top section or beneath the bottom section. The double-section gate is used less frequently because removing the gate from the slot is more cumbersome, sealing is more complicated, and additional length of pier is required. This type is useful for skimming ice and trash; however, that function can also be performed by shallow top sections of a multiple-section gate that are lifted clear of the pool.

c. *Outlet gates*. Often, lift gates are used for emergency closure of water intake systems or outlet works. Their normal operation is in the open position. They are not used for throttling flows; however, they are used to stop flow under operating conditions. They normally rest on dogging devices during normal operation. In emergencies, they are lowered into the closure slot to stop the flow of water.

(1) Powerhouse. Emergency gates are required for sudden closure of the turbine intakes to prevent subsequent damage to the turbines or powerhouse. These types of gates are normally framed with horizontal girders and a downstream skin plate. Upstream skin plates may be used when silt or mud fills up girder webs. Diaphragms are used to transfer vertical loads from the hoists. The hoisting system uses either hydraulic cylinder(s) or wire ropes. The type of hoisting system will be based on economics and governing criteria for closure times under emergency conditions. The hoisting system for wire ropes may be deck mounted or placed in recesses above the high pool elevation. Cylinders for the hydraulic system are mounted below the deck in the intake gate slot. See EM-1110-2-4205 for additional information and requirements. Because these gates must be capable of operating under full head and flowing water, tractor type gates are used to reduce friction. See paragraph 2.3 for descriptions of types of end supports. Plates 7, 8, and 9 depict this type of gate.

(2) Outlet works. Emergency closure gates for outlet works are similar to those used in powerhouses and are often used for service gates and flow control. Using tractor gates for fully submerged outlet works, as used in intake towers, is usually advantageous due to the reduced friction under full head and flow. However, many gates use wheels where loading allows. The hoisting system may require the use of a gantry crane or its own hoisting system, either wire rope or hydraulic.

2-3. Types of End Supports

End supports for vertical lift gates may be classified according to the method used to transfer the loads to the gate guides. The gate guides receive the main reaction component from horizontal loads.

a. Fixed wheel. With this type of end support, the wheels revolve on fixed axles, which are either cantilevered from the body of the gate or supported at each end by the web of a vertical girder(s) attached to the gate frame. The wheels may also be mounted by pairs in trucks that carry the wheel loads through center pins to end girders attached to the gate frame. When gate hoisting occurs with no static head, this type of end support will usually be most economical. The fabrication is generally less costly than using tractor type end supports, described in (*b*) below. When the gate is used for outlet works, this type of end support will receive higher point loads. This will cause a much higher bearing stress to the wheel and guides, as well as shear, bearing, and bending forces to the center pins and end girder. This type of end support is normally used in navigation lock gates or where the gate is used to control flows while under low static head as with spillway gates or emergency closure gates. When used for navigation lock gates, the wheels normally rest in a wheel recess to prevent them from transferring hydrostatic loads. With the wheels in the recess, horizontal loads are transferred through an end bearing shoe to the pier bearing surface. Hence the wheels carry no hydrostatic load. Hydrostatic load is then transferred from end bearing shoes on the gate to the gate guides. Refer to Chapter 6 for design and detailing information.

b. Tractor (caterpillar). This type of end support, also referred to as caterpillar, has at each side of the gate one or more endless trains of small rollers mounted either directly on members attached to or on the vertical end girder. This type of end support system is shown in Plates 8 and 9. Roller details are depicted in Plate 7. These are more commonly found on emergency closure gates or gates that control flow under high head. Because load transfer is achieved by uniformly distributed bearing through the small rollers, they are able to withstand large horizontal loads while being lowered under full hydrostatic head. Their main advantages over fixed wheels are a lower friction component while hoisting under load, lower bearing stresses transferred to the guides and gate framing, and shear and bending not transferred to the gate through the axle. When compared to slide gates, the main advantage is reduced friction, which reduces the hoisting effort required for controlling flow. This reduced friction also reduces the wear and maintenance compared with those of slide gate seal surfaces.

c. Slide. Slide gates use metal to metal contact for end support. A machined surface that is mounted to the front face of the gate bears directly against a machined guide surface in the gate slot. The two bearing surfaces also serve as the gate seal. Materials for the gate seal surface may include aluminum, bronze, or stainless steel. These types of gates are normally used in intake/outlet tunnels where a head cover (bonnet) is used to seal off the guide slot from the gate operator for submerged flow installations. They can be used for high heads; however, the head during flow control in combination with the width and height of the inlet/outlet tunnel will determine the feasibility for using slide gates. The bearing surfaces of the guides and slide bearings must be machined to tight tolerances to maintain a seal for the gate. This requires tighter construction tolerances for installation of the guides and slide bearings than with tractor gates and fixed-wheel gates, which use J seals along a seal plate.

d. Stoney. Similar to a tractor gate, a Stoney gate uses a small train of rollers; however, the fundamental difference is that the roller axles are held in position by two continuous vertical bars or angles on either side of the roller. The load is transferred from a bearing surface on the gate, through the rollers, to the guide bearing surface on the monolith. The entire roller train is independent from the gate and the guide, which allows free movement of the roller train. In order to maintain the roller train in its proper vertical position, it is common to use a wire rope support. The rope is fixed to a point on the gate, passes around a sheave fixed to the roller train, and is fixed to a point on the pier or monolith. Lateral movement is prevented by vertical bars or axles along the guide surfaces. A unique feature of this type of load transfer system, as in tractor gates, is that axle friction is not developed; hence there is a much lower friction component attributed to rolling friction. The main advantages of this type of gate support system are the same as those for the tractor gates.

2-4. Advantages/Disadvantages

a. General. The use of overhead or submersible lift gates for navigation locks versus miter gates, sector gates, or submersible tainter gates would be based on economics, riverflow operational criteria, and navigation lock configuration. Some of the main advantages of using vertical lift gates are ease of fabrication, considerably shortened erection time, and in most cases, shorter monoliths or supporting piers for spillways, powerhouse intakes, and navigation locks compared with those of tainter or radial gates. The load from the gate to the supporting pier or monolith is in one direction, simplifying the design of the supports. One main disadvantage when using vertical lift gates that are under constant cyclic loading is that the main load resisting frame relies on a tension flange or, in the case of an arch, tension tie. In these cases fatigue plays a primary role in their design. The use of fixed-wheel, tractor, Stoney, or slide gates versus tainter gates for spillways and outlets also depends on head, size of gate, riverflow operational criteria, and economics.

b. Navigation locks. For high lift requirements, or when the leaf of a submersible gate must rest on the bottom of the lock chamber or in a recessed sill, an overhead gate would be more desirable than a submersible gate. In the case where submersible leaves rest on the bottom of the lock chamber or in a recessed sill, silt would lead to hoisting problems, weak axis loading to the girders, and higher maintenance costs. Where there are high lift requirements, a submersible gate would require multiple leaves to obtain the lift required to pass river traffic. This may not be advantageous when considering hoisting arrangements and costs. Where debris and ice must be passed through the lock, a submersible gate would be more advantageous than an overhead, miter, or sector gate. For a multiple-leaf submersible gate, the downstream leaf is lowered to allow flow through the lock to pass ice or debris. A disadvantage of the use of overhead lift gates is that a tower is required to house the mechanical equipment and to gain sufficient lift for barge traffic to pass through the lock. This can cause increased design effort, in which flexibility in the tower must be accounted for in the design of the guide/hoisting system. Undesirable cracking of the monolith can occur if the tower/ monolith interface is not designed to account for the tensile stresses developed from flexure of the tower. This was observed in Ice Harbor's navigation lock, Snake River, Washington, shortly after it was placed in service.

c. Spillway. For spillway crest gates, tainter gates are preferred over vertical lift gates. This is due primarily to lower maintenance. When multiple-section vertical lift gates are required, the latching mechanisms can become inoperable unless continued maintenance is performed. This can increase maintenance activities and should be avoided if possible. However, vertical lift gates would be preferred to tainter gates when the elevation of the maximum controlled pool is so far above the sill that excessively long piers would be required for tainter gates or flood discharges or drift conditions are such that any obstruction to the flow below the bottom of the spillway bridge is undesirable, requiring the gate to be removed.

d. Outlet gates. For powerhouse intake gates the normal preference for use would be a vertical lift gate, due primarily to savings in the length of the intake pier and ease of construction. The time savings would occur for gates used for outlet works. Normal use for these types of gates is a tractor gate due to its low friction during operation. The size of gate and head requirements determine the feasibility of slide, fixed-wheel, or tractor gates. Slide gates require precise machined tolerances on the seal surfaces from the gate to the bearing guides. This requires careful quality control during field installation. Wear and damage to the slide and bearing surfaces due to use and cavitation can require higher maintenance to the slide gate. It may be more cost effective to replace wheels, rollers, or seals on a fixed-wheel or tractor gate than to fill and machine the gate and bearing surfaces of a slide gate.